1889MNRAS..49..267D

The Greenwich Standard Right Ascensions for 1880·0.

By A. M. W. Downing, M.A.

The Greenwich Clock-Star List for 1889 gives the assumed mean Right Ascensions of clock stars deduced from the "Standard Mean Right Ascensions for 1880, January 1, based on 12-hour groups," printed at the end of the Introduction to the Ten-Year Catalogue. The proper motions used are taken from Auwers' "Neue Reduction der Bradley'schen Beobachtungen," for all stars except μ *Andromedæ*, for which Main's proper motion has been used as heretofore. For δ *Sculptoris* the proper motion is taken from the Cape Catalogue 1880, and is the same as that adopted in the British Association Catalogue. A comparison, therefore, of the R.A.'s of the Greenwich Clock-Star List for 1889 with those of the *Berliner Jahrbuch* for the same year will give the systematic differences between the Greenwich Standard Right Ascensions for 1880·0 and those of Auwers' *Fundamental Catalog* (from which the *Berliner Jahrbuch* places are deduced), and may be of sufficient interest to warrant its publication in the *Monthly Notices.*

The Berlin places of μ *Andromedæ* and δ *Sculptoris* have been corrected for the effect of difference in the adopted proper motions, the Greenwich values being used in both cases. The stars common to the Greenwich and Berlin lists have then been arranged in order of declination, and the differences taken. The following table exhibits the individual differences for these stars, taken in the sense Greenwich – Berlin, or correction to the *Berliner Jahrbuch*; and there are added, for comparison, columns giving the differences Greenwich 1880—*Nautical Almanac* 1889, or correction to the *Nautical Almanac*, and Greenwich 1880—Greenwich Clock-Star List for 1888 (the places of which have been brought up to 1889), or correction to the latter Clock-Star List. It will be remembered that the Right Ascensions of these stars in the *Nautical Almanac* for 1889 have been derived, practically, from the Standard Mean Right Ascensions for 1872·0, published in the Introduction to the Greenwich Nine-Year Catalogue, the adopted proper motions being those determined by Main or Stone, whilst the Right Ascensions of the Clock-Star List for 1888 have also been derived from the same Standard Mean Right Ascensions, but with the aid of Auwers' proper motions, except in the above-mentioned cases. The proper motions adopted in the *Berliner Jahrbuch* for 1889 are, of course, those of Auwers, referred to above.

1889MNRAS..49..267D

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
α Lyræ	+38·7	−0·047	+0·011	+0·009
μ Andromedæ	37·9	− ·071	...	+ ·015
β Andromedæ	35·0	− ·070	− ·043	− ·031
β^1 Lyræ	33·2	− ·033	+ ·028	+ ·005
ι Aurigæ	33·0	− ·070	+ ·049	− ·013
ζ Herculis	31·8	− ·069	− ·066	− ·038
ε Herculis	31·1	− ·026	...	+ ·005
ρ Bootis	30·9	− ·027	− ·001	+ ·007
ζ Cygni	29·8	+ ·003	+ ·058	+ ·033
ε Andromedæ	28·7	− ·033	...	− ·006
β Tauri	28·5	− ·018	− ·024	+ ·006
α Andromedæ	28·5	− ·016	+ ·024	+ ·017
β Geminorum	28·3	− ·024	+ ·022	+ ·003
6 Cancri	28·1	− ·049	+ ·012	− ·035
μ Herculis	27·8	− ·073	− ·004	− ·033
32 Vulpeculæ	27·6	− ·041	+ ·015	+ ·009
ψ Bootis	27·4	− ·036	− ·034	− ·010
α Coronæ	27·1	− ·035	− ·007	+ ·002
μ Leonis	26·5	− ·036	+ ·034	− ·012
16 Pegasi	25·4	− ·033	− ·022	+ ·004
ι Pegasi	24·8	− ·016	...	− ·004
ε Leonis	24·3	− ·009	+ ·017	+ ·021
μ Pegasi	24·0	− ·016	...	+ ·003
η Tauri	23·8	− ·013	+ ·012	+ ·005
α Arietis	22·9	− ·030	+ ·027	+ ·018
τ Tauri	22·7	− ·007	...	+ ·001
μ Geminorum	22·6	− ·047	− ·057	− ·036
η Geminorum	22·5	− ·035	+ ·018	− ·017
δ Geminorum	22·2	− ·023	− ·057	+ ·003
δ Leonis	21·1	− ·016	− ·003	+ ·009
ζ Geminorum	20·7	− ·052	...	− ·035
η Cancri	20·7	− ·049	− ·002	− ·024
β Arietis	20·3	− ·033	+ ·042	− ·005
α Bootis	19·8	− ·010	+ ·015	+ ·028
γ Herculis	19·4	− ·002	+ ·002	+ ·015
δ Arietis	19·3	− ·025	− ·017	− ·004
η Bootis	19·0	− ·035	− ·035	− ·022
ε Tauri	18·9	− ·057	+ ·009	− ·025

1889MNRAS..49..267D

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	
83 Cancri	+18·2	−0·023	+0·070	+0·017
τ Bootis	18·0	− ·033	− ·015	− ·004
γ Geminorum	16·5	− ·038	+ ·030	+ ·010
α Tauri	16·3	− ·012	− ·009	·000
γ Serpentis	16·0	− ·015	...	− ·006
α Delphini	15·5	− ·013	...	+ ·012
γ Tauri	15·4	− ·037	− ·020	+ ·010
β Leonis	15·2	− ·006	+ ·010	+ ·003
ε Aquilæ	14·9	− ·047	+ ·051	·000
ν Orionis	14·8	− ·047	− ·055	− ·032
η Piscium	14·8	− ·037	− ·014	− ·010
α Pegasi	14·6	− ·008	+ ·003	+ ·009
γ Pegasi	14·6	− ·042	− ·024	− ·011
α^1 Herculis	14·5	− ·030	+ ·019	+ ·002
ζ Aquilæ	13·7	− ·009	+ ·069	+ ·011
ξ Geminorum	13·0	− ·020	− ·061	− ·033
α Ophiuchi	12·6	− ·019	+ ·058	+ ·013
f Tauri	12·6	− ·041	...	− ·025
α Leonis	12·5	− ·007	+ ·025	+ ·009
α Cancri	12·3	+ ·032	+ ·072	+ ·053
ε Virginis	11·6	− ·033	− ·043	− ·023
ω Aquilæ	11·4	− ·031	+ ·019	− ·010
l Leonis	11·1	− ·043	+ ·012	− ·016
ε Delphini	10·9	− ·024	·000	− ·008
ο Leonis	10·4	− ·036	+ ·027	− ·021
γ Aquilæ	10·3	− ·019	− ·012	+ ·014
ζ Pegasi	10·3	− ·020	− ·057	− ·002
ρ Leonis	9·9	− ·047	− ·047	− ·027
κ Ophiuchi	9·5	− ·019	+ ·025	− ·006
β Cancri	9·5	− ·036	− ·031	− ·026
72 Ophiuchi	9·5	− ·011	− ·003	+ ·007
ε Pegasi	9·4	− ·032	− ·046	− ·006
ο Virginis	9·3	− ·035	...	− ·021
ο Tauri	8·6	− ·045	− ·104	− ·011
π Leonis	8·6	− ·014	− ·017	− ·001
ο Piscium	8·6	− ·023	− ·042	+ ·010
α Aquilæ	8·6	− ·026	− ·012	+ ·004
β Canis Min.	8·5	− ·032	− ·021	− ·018

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
χ Leonis	+8·0	+0·024	+0·015	+0·040
ξ² Ceti	8·0	− ·032	− ·001	− ·001
α Orionis	7·4	+ ·001	+ ·017	+ ·020
ε Piscium	7·3	− ·024	− ·072	+ ·014
δ Piscium	7·0	− ·035	+ ·009	·000
ε Hydræ	6·8	− ·017	+ ·009	+ ·017
α Serpentis	6·8	− ·037	− ·026	− ·005
ω Piscium	6·2	− ·029	− ·035	− ·013
β Aquilæ	6·1	− ·042	− ·046	− ·023
α Canis Min.	5·5	+ ·019	+ ·098	·000
ι Piscium	5·0	− ·032	− ·044	− ·016
ν Piscium	4·9	− ·024	+ ·023	+ ·013
α Equulei	4·8	− ·009	...	+ ·008
ε Serpentis	4·8	− ·014	− ·053	+ ·001
β Ophiuchi	4·6	− ·014	+ ·037	+ ·018
δ Virginis	4·0	·000	− ·050	+ ·014
α Ceti	3·7	− ·008	+ ·014	+ ·031
δ Aquilæ	2·9	− ·036	+ ·030	+ ·008
γ² Ceti	2·8	− ·041	+ ·012	+ ·020
γ Piscium	2·7	− ·001	+ ·046	+ ·017
β Virginis	2·4	+ ·022	...	+ 0·15
λ Ophiuchi	2·2	− ·026	...	+ ·007
τ Virginis	2·1	− ·021	− ·041	− ·015
κ Piscium	+0·6	+ ·001	+ ·004	+ ·019
ζ Virginis	0·0	− ·016	− ·035	− ·008
η Virginis	−0·1	− ·030	+ ·005	− ·020
υ Leonis	0·2	− ·018	+ ·024	+ ·005
δ Ceti	0·2	− ·048	...	− ·028
δ Orionis	0·4	− ·036	− ·051	− ·010
η Aquarii	0·7	− ·021	+ ·024	+ ·004
α Aquarii	0·9	− ·006	+ ·052	+ ·015
θ Aquilæ	1·2	− ·006	− ·003	+ ·014
ε Orionis	1·3	− ·005	+ ·021	+ ·017
γ Aquarii	1·9	− ·010	+ ·019	+ ·020
η Serpentis	2·9	− ·008	− ·002	+ ·013
δ Ophiuchi	3·4	− ·033	+ ·016	− ·003
μ Eridani	3·5	− ·014	− ·048	− ·010
12 Ceti	4·6	− ·050	+ ·012	− ·021

1889MNRAS..49..267D

1889MNRAS..49..267D

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
θ Virginis	− 4·9	+0·014	+0·010	+0·014
β Aquarii	6·1	− ·036	+ ·012	+ ·005
67 Ceti	6·9	− ·032	+ ·025	+ ·016
o^1 Eridani	7·1	− ·081	− ·012	− ·035
α Hydræ	8·2	− ·034	+ ·023	− ·012
λ Aquarii	8·2	− ·002	+ ·120	+ ·043
β Orionis	8·3	− ·004	+ ·010	+ ·013
θ Aquarii	8·3	− ·037	+ ·024	+ ·028
θ Ceti	8·8	− ·064	− ·021	− ·023
β Libræ	9·0	− ·028	+ ·022	+ ·005
ι Ceti	9·4	− ·012	+ ·068	+ ·019
κ Orionis	9·7	+ ·008	− ·008	+ ·019
ε Eridani	9·8	− ·021	− ·004	+ ·005
κ Virginis	9·8	− ·039	...	− ·027
ε Aquarii	9·9	− ·004	+ ·043	+ ·029
δ Eridani	10·1	− ·015	...	− ·035
ζ Ophiuchi	10·3	− ·027	− ·033	− ·002
α Virginis	10·6	− ·026	+ ·007	− ·002
θ Canis Maj.	11·9	− ·053	− ·041	− ·033
α^2 Capricorni	12·9	− ·008	+ ·033	+ ·013
γ^1 Eridani	13·8	− ·007	+ ·031	+ ·016
δ Crateris	14·2	− ·001	− ·036	− ·010
β Capricorni	15·1	− ·015	...	+ ·029
γ Canis Maj.	15·5	− ·008	− ·103	− ·033
α Libræ	15·6	− ·012	− ·035	+ ·007
η Ophiuchi	15·6	− ·006	+ ·010	+ ·023
δ^2 Corvi	15·9	− ·065	− ·166	− ·035
μ Hydræ	16·3	− ·038	− ·041	− ·045
δ Capricorni	16·6	− ·023	...	− ·006
β Canis Maj.	17·9	− ·036	...	− ·017
α Leporis	17·9	+ ·001	+ ·023	+ ·060
ρ Capricorni	18·2	− ·057	+ ·042	− ·015
β Ceti	18·6	− ·038	+ ·026	− ·002
ι^1 Libræ	19·4	− ·032	...	− ·003
β^1 Scorpii	19·5	− ·014	− ·012	− ·002
μ Sagittarii	21·1	− ·039	+ ·030	− ·014
ε Corvi	22·0	− ·037	− ·031	− ·015
ε Leporis	22·5	− ·050	− ·015	− ·021

1889MNRAS..49..267D

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
β Corvi	−22·8	+0·043	+0·118	+0·043
15 Argûs	24·1	− ·030	− ·024	− ·017
θ Ophiuchi	24·9	+ ·005	+ ·034	+ ·025
h^2 Sagittarii	25·1	+ ·015	− ·003	+ ·003
α Scorpii	26·2	− ·041	− ·039	− ·015
δ Sculptoris	28·7	+ ·001	+ ·004	+ ·001
ε Canis Maj.	28·8	− ·011	− ·023	− ·006
α Piscis Aust.	−30·2	− ·014	+ ·027	+ ·003

With a view to discussing the systematic corrections to the star places of the *Berliner Jahrbuch*, the stars have been combined in convenient groups, and the means of the corrections and of the declinations corresponding to each group taken. The mean $\Delta\alpha$'s have then been graphically represented, and a curve drawn through them, from which can be read off the corrections corresponding to any declination between the extreme limits. The following table, in the columns headed I., gives the computed mean corrections and the corresponding quantities as read off from the curve. The curve has been extended, on both sides, beyond the limits of the extreme mean declinations, by making use of the corrections derived from single stars situated beyond those limits. Its course is, as will be readily understood, considerably more uncertain in these parts than it is between Dec. +33°·9 and −25°·1. The corrections, read off from this curve, have then been applied, with reversed signs, to the $\Delta\alpha$ for each star; and it is considered that the outstanding differences are those depending on R.A. The stars have therefore been arranged in order of R.A. and combined in groups of 1^h each, and by a graphical representation of the mean corrections, similar to that explained above, we obtain from the curve which has been drawn the values of $\Delta\alpha$, corresponding to the mean R.A. of each group. The resulting quantities are printed in the table of corrections depending on R.A. given below. The corrections, read off from the curve last referred to, have then been applied, with reversed signs, to the $\Delta\alpha$ for each star, arranged in order of declination, which has been used in forming the first approximation to the systematic corrections depending on declination. The residuals may be considered to be free from discordances depending on R.A., and being treated exactly as before, give the second approximation to the values of the systematic corrections depending on declination. This second approximation is given in the following table, in the columns headed II. As the second approximation differs so little from the first, it was not considered necessary to proceed to a further approximation.

1889MNRAS..49..267D

Corrections depending on Declination.

Mean Dec.	Mean Δα. I.	Mean Δα. II.	No. of Stars.	Δα (from Curve). I.	Δα (from Curve). II.
°	s	s		s	s
+33·9	−0·052	−0·051	8	−0·052	−0·051
+28·0	− ·033	− ·035	11	− ·036	− ·037
+23·5	− ·023	− ·024	10	− ·028	− ·029
+19·6	− ·030	− ·031	11	− ·027	− ·028
+14·4	− ·022	− ·023	18	− ·026	− ·027
+10·0	− ·027	− ·030	20	− ·024	− ·026
+ 5·0	− ·018	− ·019	21	− ·021	− ·023
− 1·6	− ·018	− ·021	16	− ·021	− ·022
− 8·9	− ·027	− ·027	17	− ·025	− ·026
−16·2	− ·024	− ·026	17	− ·023	− ·025
−25·1	− ·016	− ·019	11	− ·016	−0·019

Corrections depending on Right Ascension.

Mean R.A.	Mean Δα.	No. of Stars.	Δα (from Curve).
h	s		s
0·4	−0·004	9	−0·003
1·5	− ·011	6	− ·009
2·5	− ·009	6	− ·007
3·5	+ ·001	7	− ·005
4·5	− ·011	7	− ·003
5·4	+ ·011	8	·000
6·5	− ·011	10	− ·001
7·6	+ ·007	5	+ ·003
8·5	+ ·007	5	+ ·006
9·5	+ ·001	6	+ ·003
10·5	+ ·002	5	+ ·006
11·5	+ ·015	6	+ ·009
12·5	+ ·001	6	+ ·006
13·6	+ ·005	6	+ ·005
14·6	+ ·006	5	+ ·005
15·6	− ·001	7	+ ·001
16·5	− ·002	8	− ·001
17·4	+ ·002	6	+ ·001
18·4	+ ·001	6	+ ·002
19·5	+ ·001	7	+ ·002
20·5	+ ·004	8	+ ·004
21·6	+ ·005	6	+ ·006
22·6	+ ·009	10	+ ·008
23·5	+ ·007	5	+ ·005

1889MNRAS..49..267D

In a paper entitled "On the Star Places of the *Nautical Almanac*," printed in the *Monthly Notices*, vol. xlv. No. 5, there will be found tables giving the systematic corrections to the star places of the *Nautical Almanac*, the *Berliner Jahrbuch*, the *American Ephemeris*, and the *Connaissance des Temps*, all for the year 1883, to reduce them to the system of the *Nautical Almanac* for 1884. The star places of the *Nautical Almanac* for 1883 were derived from the Greenwich First and Second Seven-Year Catalogues, with Main's or Stone's proper motions. Those of the *Nautical Almanac* for 1884 were derived from the Greenwich Nine-Year Catalogue, using the same proper motions. The *Berliner Jahrbuch* places for 1883 were derived from Auwers' *Fundamental Catalog*, using the proper motions of that Catalogue, as were also the Berlin places for 1889, as stated above. These tables of systematic corrections, therefore, in combination with the comparison of the Greenwich R.A.'s for 1889 with those of the *Berliner Jahrbuch* for the same year, enable us to form tables of systematic corrections to the R.A.'s of the *Nautical Almanac* for 1883, the *American Ephemeris* for 1883, the *Connaissance des Temps* for 1883, and the *Nautical Almanac* for 1884, to reduce them to the system of the Greenwich Standard Right Ascensions for 1880·0.

These final tables of systematic corrections are given below. It will be noticed that, except for the considerable difference in adopted equinox,* the Greenwich Standard R.A.'s for 1880·0 approximate closely to those of the *Fundamental Catalog*—more closely, in fact, than they do to those of the *Nautical Almanacs* for 1883 or 1884; a result which appears to be due, partly, to the adoption of Auwers' proper motions in the formation of the Greenwich mean places (the effect of which can be estimated from a comparison of the corrections to the *Nautical Almanac* for 1889 with those to the Greenwich Clock Star List for 1888, given in the first table above), and partly to the gradual elimination of periodic errors from the assumed places of the Greenwich clock-stars, which is being effected by the methods now adopted at Greenwich for the determination of Standard Right Ascensions.

Corrections depending on Declination.

Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1883.	American Ephemeris 1883.	Conn. des Temps 1883.	Nautical. Almanac 1884.
°	s	s	s	s	s
+35·0	−0·061	−0·025	−0·082	+0·020	+0·001
30·0	− ·042	− ·017	− ·058	+ ·012	·000
25·0	− ·031	− ·020	− ·042	+ ·012	− ·010
20·0	− ·028	− ·014	− ·040	+ ·016	− ·013
15·0	− ·027	− ·006	− ·043	+ ·020	− ·012

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* The difference between the equinox of the *Fundamental Catalog* and that now adopted at Greenwich is pointed out in a paper on "The Greenwich Standard Right Ascensions," published in the *Monthly Notices*, vol. xl. No. 3.

1889MNRAS..49..267D

Corrections depending on Declination.

Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1883.	American Ephemeris 1883.	Conn. des Temps 1883.	Nautical Almanac 1884.
°	s	s	s	s	s
+10·0	–0·026	–0·002	–0·046	+0·003	–0·009
+ 5·0	– ·023	·000	– ·046	– ·009	– ·010
0·0	– ·022	+ ·008	– ·042	– ·009	– ·010
– 5·0	– ·023	+ ·017	– ·039	– ·006	– ·006
10·0	– ·026	+ ·018	– ·043	– ·006	– ·008
15·0	– ·025	+ ·021	– ·044	– ·002	– ·005
20·0	– ·023	+ ·022	– ·042	– ·003	– ·002
–25·0	– ·020	+ ·024	– ·037	– ·011	+ ·006

Corrections depending on Right Ascension.

R.A.	Berliner Jahrbuch 1889.	Nautical Almanac 1883.	American Ephemeris 1883.	Conn. des Temps 1883.	Nautical Almanac 1884.
h	s	s	s	s	s
0·0	+0·001	+0·039	+0·003	+0·037	+0·026
1·0	– ·007	+ ·022	– ·006	+ ·022	+ ·005
2·0	– ·008	+ ·009	– ·007	+ ·009	– ·004
3·0	– ·006	·000	– ·004	– ·009	– ·004
4·0	– ·004	– ·013	·000	– ·036	– ·009
5·0	– ·002	– ·022	+ ·002	– ·053	– ·010
6·0	– ·001	– ·030	– ·001	– ·055	– ·013
7·0	·000	– ·029	– ·003	– ·042	– ·012
8·0	+ ·004	– ·009	+ ·002	– ·016	+ ·006
9·0	+ ·005	+ ·021	+ ·006	– ·004	+ ·030
10·0	+ ·005	+ ·022	+ ·009	– ·005	+ ·028
11·0	+ ·008	+ ·007	+ ·012	– ·009	+ ·011
12·0	+ ·007	– ·013	+ ·006	– ·019	– ·009
13·0	+ ·005	– ·025	+ ·001	– ·022	– ·017
14·0	+ ·005	– ·027	– ·002	– ·018	– ·011
15·0	+ ·004	– ·021	– ·004	– ·011	– ·006
16·0	·000	– ·014	– ·006	– ·003	– ·006
17·0	·000	·000	– ·001	+ ·008	– ·001
18·0	+ ·002	+ ·019	+ ·006	+ ·022	+ ·012
19·0	+ ·002	+ ·038	+ ·005	+ ·031	+ ·021
20·0	+ ·003	+ ·051	+ ·003	– ·038	+ ·032
21·0	+ ·005	+ ·058	+ ·003	+ ·044	+ ·040
22·0	+ ·007	+ ·060	+ ·005	+ ·047	+ ·043
23·0	+ ·007	+ ·053	+ ·007	+ ·046	+ ·039

Blackheath: March 1889.

1889MNRAS..49..267D

On a Graphical Method for determining the Orbit of a Binary Star.

By Professor S. Glasenapp.

(*Communicated by Herbert Sadler.*)

The problem of determining the elements of a binary star consists of two separate parts: (1) to obtain the apparent orbit from a series of given observations, and (2) to compute the elements of the true orbit, the apparent orbit being given. Both parts can be solved by graphical and analytical methods.

Between the true and apparent orbit exists a geometrical relation which furnishes the means for obtaining one orbit when the other is given; this is a purely geometrical problem.

The apparent orbit is never known; we can only determine the probable apparent orbit of the component stars. Each computer tries to obtain the most probable orbit.

The general equation of an ellipse, being a curve of the second degree, is—

$$\alpha x + \beta y + \gamma x^2 + \delta xy + \epsilon y^2 + 1 = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where x and y are the rectangular co-ordinates of the *comes* relative to the principal star which coincides with the origin of the co-ordinates. The plane of co-ordinates is perpendicular to the line of sight.

The coefficients of the equation (1) for an ellipse must satisfy the well-known conditions—

$$\begin{aligned}(\beta\delta - 2\alpha\epsilon)^2 - (\delta^2 - 4\epsilon\gamma)(\beta^2 - 4\epsilon) > 0,\\ \delta^2 - 4\epsilon\gamma < 0.\end{aligned} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

I should add to them the two following:—

$$\gamma < 0 \text{ and } \epsilon < 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

which represents that the principal star lies in the inner part of the ellipse—i.e. that the ellipse obtained intersects the two co-ordinate axes of x and y on opposite sides of the principal star. If the conditions (3) are not fulfilled all the parts of the ellipse lie outside the principal star. In this case, in determining the elements of the true orbit by the usual methods, we shall obtain imaginary elements.

Let us now consider a very simple method for determining the coefficients α, β, γ, δ, and ϵ of the general equation (1).

Let us assume that the apparent ellipse is drawn with such care as is generally employed in graphical methods.

If we put $y=0$, the equation (1) will be reduced to an equation of the second degree in x—

$$\alpha x + \gamma x^2 + 1 = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

whose roots are the co-ordinates of the two points where the